Research Paper | Biology | E-ISSN No : 2454-9916 | Volume : 9 | Issue : 7 | July 2023

# EVALUATING STEM BROADENING PARTICIPATION INITIATIVES

Lawrence O. Flowers

PhD, Associate Professor of Biology, Department of Biological and Physical Sciences, Saint Augustine's University

## ABSTRACT

A highly structured evaluation plan is essential to implementing a successful science, technology, engineering, and math (STEM) intervention program designed to improve diversity in STEM education and careers. Effective program evaluations facilitate program improvement and sustainability goals. This article reviews paramount program components and discusses the importance of integrating program components in designing a dynamic evaluation plan. Evaluation plan development must involve dialogue with program team members and participants before, during, and after the STEM intervention. Translation of raw data to actionable intelligence using appropriate analytical techniques is indispensable to maximize the insights derived from an effective evaluation plan.

**KEYWORDS:** Evaluation, Logic Model, Benchmarks, Formative, Summative

## INTRODUCTION

This article offers a straightforward approach to program evaluation for STEM initiatives designed to broaden participation in the STEM pathway. Program evaluation is essential to academic and professional development programmatic interventions. The entire project team should play a role in the program evaluation's development, implementation, and completion. The program evaluation may be complicated and involve many elements; however, all program evaluations encompass at least four main components. The four components include: 1) the determination of the scope of the STEM program, 2) the formation of the goals and objectives of the program, 3) the development of critical metrics and initiation of measurement strategies, and 4) the review and response to evaluation data.

Business, education, and organizational management journals have highlighted the importance of benchmarks and indicators. Benchmarks and indicators are essential elements of effective evaluation algorithms. The practical difference between a benchmark and an indicator is that benchmarks are goals to accomplish or standards that serve as a basis for comparing with other programs, usually based on best practices and empirical precedent. Indicators represent a more specific way of articulating objectives or goals, typically involving numerical and time components. Develop benchmarks by studying the metrics of similar successful STEM programs. Develop process-oriented, strategic, and organizational performance benchmarks. Consult other articles to learn the most advantageous way to visualize benchmarks and indicators.

Establish benchmarks and critical performance indicators (CPIs) for individual program team members, program participants, and program components. Moreover, benchmarks and indicators allow quick performance quantification to determine adherence to goals, objectives, outcomes, and impacts. Benchmark and indicator formulation provides the fundamental framework to elucidate essential program information to enhance the STEM program. Perform a needs analysis to determine the baseline for benchmarks and indicator establishment. Consider benchmarks as long-term goals and indicators as short-term goals used to monitor the progress of benchmark completion. Use benchmarks to evaluate semesterly or yearly success and indicators to track weekly or monthly adherence to program objectives. Failure to achieve goals and objectives highlights key areas of concern and potential improvement.

### Logic Model

A logic model is a valuable visual representation that illustrates the interconnections between components of a program (e.g., resources, intervention, evaluation, and post-evaluation) (Jones et al., 2020). Logic models are used in academic and business environments (Cooper et al., 2020; Strycker, 2016) and constructed using different designs. Typically, a logic model depicts the problem, inputs, outputs (e.g., strategies, activities, participants), outcomes, assumptions, barriers, impacts, and evaluation plan. The logic model is a blueprint that documents how program resources and actions are connected to achieve the desired outcomes and institutional or societal impacts. The logic model schematic can also help communicate program goals to various stakeholders. As previously mentioned, typically, the logic model includes the program evaluation plan; however, a logic model can also be designed exclusively for the program evaluation. Figure 1 shows a generalized logic model adaptable to any STEM program framework. Table 1 details specific inquiries that must be addressed and included in the logic model.

| Program Title: |
|---|
| Problem: |
| Inputs: |
| Outputs: |
| Outcomes: |
| Impacts: |
| Assumptions/Barriers: |
| Evaluation: |

**Table 1. Logic Model Elements, Definitions, and Questions**

| Logic Model Elements | Definitions | Questions |
|---|---|---|
| Problem | Primary issues, needs, or priorities addressed by the STEM initiative. | What is the nature of the problem or issue that requires a positive solution? |
| Inputs | Human, financial, infrastructural, intellectual, and material resources. | What resources do I have? What resources do I need for a successful STEM program? |
| Outputs | Strategies, activities, participants, research methods, or stakeholders. | What specific methods or activities will be employed during the intervention? Who are my primary participants, audience, or beneficiaries? |
| Outcomes | Effects of a successful implementation. | What are the short-term, intermediate, and long-term goals of the program? |
| Impacts | Future positive impacts with broad implications. | Did the intervention result in significant societal changes? Did the program have consequential impacts on education, the economy, policy, or the workforce? |
| Assumptions/Barriers | Perceptions, beliefs, or ideas about the STEM broadening participation initiative. Implicit or explicit impediments to program completion. | What are the potential assumptions or obstacles that could negatively affect successful implementation? |
| Evaluation | Determination of STEM program effectiveness. Strategies to monitor adherence to the mission, vision, goals, and objectives. | Have the goals and objectives been achieved? How can the STEM program be improved now and in the future? |

**Figure 1.** Generalized adaptable STEM program logic model outline.

## STEM PROGRAM

Before developing a specific evaluation plan, consider paramount institutional and program elements. Those elements include formulating the vision statement,

mission statement, goals and benchmarks, objectives and indicators, and program activities. Once these items are clearly defined, establishing the evaluation plan becomes a much simpler process.

**Vision**

The STEM program vision statement offers a prosperous global overview of the program's future aspirations. Your program's vision statement must be consistent and aligned with the institutional vision statement. The program vision statement is usually brief and comprises one or two sentences. The vision statement will allow for continual refocusing of team members during the program. Sample vision statements could include: "To create career opportunities for all students," "To stimulate learning and research to transform society," "To inspire the next generation of scientific talent," and "To provide access to information to change the world."

**Mission**

In contrast to the vision statement, the program mission statement is typically longer, such as five-ten sentences, and provides more details about how your program or organization will actualize its vision. The mission statement is a broad and concise statement that provides an overview of the broadening participation program that documents the strategic goals and purpose. It gives more specific information regarding what the STEM program must do to pursue its aims. Both the program team and stakeholders benefit from a well-crafted mission statement. The internet is replete with excellent academic institutions and company mission statements. To better understand the best components for a program mission statement, read several mission statements online and apply similar ideas to the program's mission statement. It is also important to ensure that each member of the project team and institutional administrators play a role in developing the mission statement to enhance buy-in.

**Goals**

Setting program goals is not easy and should once again require tremendous input from the entire team and external stakeholders. Goals represent programmatic endpoints or mark a desired result. In the system discussed herein, goals or outcomes may be short-term, intermediate, and long-term. Goals represent a distillation of the mission statement. The goals or outcomes section is different from the vision statement and mission statement because this section allows project officials to present a realistic view of likely programmatic outcomes following effective implementation. The vision and mission statements are less specific than goals or outcomes statements which are more specific. In addition, to being outcome-oriented, they can also be process-oriented. The key is ensuring that the tenets in this section reflect the true nature of the program components and activities and that the goals and outcomes are achievable.

**Objectives**

Objective statements are more specific than goal statements and present measurable and actionable program directives to achieve goals. Each goal statement should include at least three-five objective statements. Create SMART statements. SMART objectives refer to constructing ideas that are specific, measurable, achievable, relevant, and completed within a certain timeframe. These statements contain categorical and continuous variables that are easy to measure using standard or advanced statistical procedures. Use precise indicators to monitor adherence to program objectives.

**Table 2. Common STEM Program Indicators**

| Project Areas | Indicator | Target Action |
|---|---|---|
| Recruitment | 1. Project website traffic<br>2. Online applications<br>3. Recruitment emails<br>4. Recruitment presentations | 1. Increase the number of new visitors by 10% monthly.<br>2. Increase the number of applicants by 20% monthly.<br>3. Increase the number of emails sent by 10% weekly.<br>4. Increase the number of program recruitment presentations by 10% monthly. |
| Program | 1. Comprehension of concepts and skills<br>2. Supply order fulfillment<br>3. Infrastructure enhancements<br>4. Partnerships and collaborations | 1. Improve post-test scores on quantitative surveys.<br>2. Decrease the time of receipt of materials by 10% yearly.<br>3. Increase the number of instruments by 25% yearly.<br>4. Increase the number of new letters of collaboration by 10% quarterly. |
| Evaluation | 1. Formative and summative reports<br>2. Internal evaluation<br>3. External evaluation<br>4. Benchmarks and indicators | 1. Increase the number of formative evaluation reports by 10% monthly and decrease the completion time of the summative (e.g., annual) report by 20% yearly.<br>2. Increase internal evaluator meetings by 10% yearly.<br>3. Increase external evaluator meetings by 10% yearly.<br>4. Develop new benchmarks and indicators and modify existing statements. |

The design of participant learning objectives and program learning objectives is paramount to effective evaluation plans for STEM initiatives. Objective statements should reflect the program requirements and expectations and be expressed concisely and unambiguously. Well-written objectives also provide a harbinger of potential assessment methods to measure compliance. Communicate program objectives to program participants on the first day of the program and include them in online materials. Construct objective statements to focus on what participants will learn, do, or understand from the broadening participation program. Clear, unambiguous, accurate directives also provide recommendations for direct program implementation strategies and activities. Most course syllabi contain information that specifies what students should know or be able to do after the course has ended. Consultation of online course syllabi in STEM disciplines will present some excellent ideas for quality objective statements.

Moreover, use objective statements to create indicators during the program to monitor goal attainment. Effective indicators involve numerical measurements tracked before, during, and after the program, such as participant recruitment, enrollment, internships, research experiences, number of graduates, target GPAs, seminars, workshops, research equipment, publications, number of new job hires, and number of new program, departmental, and institutional collaborations. Objectives and indicators must be quantifiable and measurable and include target actions (Table 2). These and other critical performance indicators help keep the team focused on the metrics that matter.

**Strategies**

After you have crafted the project vision statement, mission statement, goals, and objectives, it is time to develop and document the nuts and bolts of the program. Establish strategies that result in satisfying aims within the target time frame. Program activities should be extremely detailed. Research the literature for best practices to facilitate successful interventions. Each objective statement should include three-five specific strategies to accomplish the objective. Specify which team member will be responsible for a particular task. Make sure they know how to report metrics and document completion correctly.

**Program Evaluation**

After the components of the STEM initiative, such as vision, mission, goals, objectives, and strategies, are elucidated, documented, and implemented, it is time to utilize quantitative and qualitative methods to assess adherence to your program's vision, mission, goals, and objectives. Generally, program evaluations involve observational research and empirical assessments to produce evidence of STEM program compliance and effectiveness. The evaluation plan may involve the periodic measurement of academic success, achievement, perceptions, motivation, career development skills, research skills, pedagogical skills, communication skills, and other critical outcomes that determine educational and career success in STEM (Flowers, Flowers, & Moore, 2016). Incorporate a social scientist into the program team to facilitate the program evaluation. Social scientists understand basic and advanced evaluation methods and should lead the discussion on best practices in assessment, analytical procedures, and data presentation methods.

The program evaluation must involve multiple formative and summative phases. Formative evaluation components refer to adherence or program monitoring procedures performed during the program. For example, if your STEM program runs for the entire academic year (e.g., Fall and Spring semesters), your formative evaluation may occur weekly, monthly, or semesterly. In an educational context, formative assessments typically include quizzes, homework, or daily journals. Depending on the nature of the STEM program, formative assessments could assess program participants, team members, or other aspects of the initiative. Formative assessments facilitate reactive feedback from participants and staff. Formative evaluations allow program directors and principal investigators to make substantive, immediate, and continuous instructional or programmatic changes in real time.

Summative evaluations, on the other hand, occur at the end of the course, year, or program. Summative monitoring procedures check for adherence to outcomes and impacts. For example, suppose a STEM program runs for the entire academic year for three years. In that case, the summative evaluation may occur yearly or several years after the program ends. Formative assessments provide formal or informal estimates of program participant progress. Summative assessments provide formal (e.g., post-test) estimates of global understanding and impacts after completing the STEM experience. Formative assessments allow teams to determine what participants learn or perceive during STEM-based interventions. Summative assessments will enable teams to determine the extent of the learning gains. Summative assessments also produce data that encourages accountability and generates strategies for future implementation. Authentic assessments such as skills-based tasks, scientific communication tasks, and comprehensive questionnaires are the preferred participant

summative assessments to confirm proficiency and competency in key program areas (Sabtiawan, Yuanita, & Rahayu, 2019). For both formative and summative assessments, rubrics and clearly defined benchmarks may be helpful to measure knowledge, perceptions, and skills adequately (Chan & Ho, 2019).

As mentioned in the introduction section, a comprehensive STEM program evaluation plan must include four common elements: 1) the determination of the scope of the STEM program, 2) the formation of the goals and objectives of the program, 3) the development of critical metrics and initiation of measurement strategies, and 4) the review and response to evaluation data. After the data is collected, the important task is to sift through the copious amounts of data to determine if the measurement strategies were effective and to meticulously probe the data to assess program efficacy. It is essential to thoroughly examine the research literature to uncover critical questions, knowledge gaps, mixed methods instruments, and issues that disciplinary experts deem important for participant development and success (Okulu & Oguz-Unver, 2021). Conducting or locating meta-analyses and systematic reviews may help to plan a practical evaluation framework. Understanding how the literature's critical issues and unresolved questions align with the objectives and outcomes of the program may lead to helpful evaluation questions and a robust evaluation plan.

Integrate online organizational work management application platforms such as Monday.com, Asana.com, Trello.com, and Proofhub.com to improve evaluation plan efficiency and keep team members on the same page. Features on these platforms allow for daily electronic communications and visually appealing task-based solutions to enhance accountability. While the platforms mentioned above are subscription based, which may not be cost-effective, using Google Calendar and other free scheduling applications can also be useful. Further, using electronic data collection platforms such as Survey Monkey and Google Forms is the preferred strategy for collecting assessment data. Paper-based data collection systems lead to reductions in accuracy, response rates, productivity, and actionable intelligence. The increased accessibility of mobile phones and other mobile technology allows project directors to reach potential survey respondents quickly.

Consider oversampling and power analysis procedures when collecting critical data that may determine the effectiveness of the STEM initiative (Rickles, Zeiser, & West, 2018). Student attrition may negatively impact evaluation metrics. Following the successful implementation of the STEM program evaluation, document the successful execution of the evaluation plan in the form of educational literature. Furthermore, following a review of the formative and summative assessment data, utilize the data to fix problems or create new solutions to ensure adherence to program goals and objectives. Table 3 provides examples of evaluation schemes.

**Table 3. Evaluation Literature**

| Initiative | Target Implementation Audience | References |
|---|---|---|
| Curriculum | Pre-service Teachers STEM initiative. | Dede (2022); Türk, Kalayci, & Yamak (2021)a positive solution? |
| Academic Success | Undergraduates | Howley, Campbell, Cowley, & Cook (2022); Windsor & Ivey (2018) |
| Research Experiences | Undergraduates | Pitre, Mlsna, & Mlsna (2022); Zhao (2022) |
| Graduate Programs | Graduate Students | Brace et al. (2018); Reeves, Claydon, & Davenport (2022) |
| Bridge Programs | Undergraduates | Bradford, Beier, & Oswald (2021); Greer, Chi, & Hylton-Patterson (2023)policy, or the workforce? |
| Mentoring | STEM Faculty and Undergraduates | Bradley & Mead (2022); Rockinson-Szapkiw, Sharpe, & Wendt (2022) |

## CONCLUSION

Broadening participation in STEM education and careers to create a more equitable and prosperous society remains a paramount and elusive vision. Data published by the National Science Foundation demonstrates that despite enormous gains in enhancing diversity at every step of the STEM pathway, additional work is required to achieve goals that impact underrepresented populations. Develop and implement beneficial STEM initiatives such as career development workshops, undergraduate research experiences, coding boot camps, summer academic bridge programs, and undergraduate, graduate, and faculty mentoring programs that produce impactful metrics.

Initiatives designed to improve diversity and training opportunities for underserved communities are meaningful and have enhanced numerous student achievement measures and professional outcomes. Undergraduate research experiences continue to be a frontrunner of beneficial strategies to help students actualize their true potential and guide career decisions (Borrego et al., 2021; Bruthers & Matyas, 2020; Ghebreyessus et al., 2022; Yang et al., 2019). More effective program evaluation schemes could elucidate better approaches to integrate undergraduate research into the STEM curriculum. Moreover, additional research is needed to study diverse evaluation plans to develop best practices for programs involving minority students and minority-serving institutions.

STEM program evaluation involves the development of program aspirations and carefully constructing specific strategies for accomplishing program goals. Specific techniques include using qualitative questionnaires and quantitative surveys designed to collect detailed information from target audiences in a specified period. It also involves tracking, monitoring, and adhering to compliance and correcting activities to fix the program if things are not trending in the right direction. Evaluation systems must apply evaluative strategies to assess outcomes and implementation procedures (Onyura et al., 2022). Be conscious of reciprocity and interconnectivity when considering the evaluation plan. Understand that every component of the STEM program ultimately impacts the bottom line. Thus, the comprehensive evaluation scheme must contain objectives to evaluate every participant, strategy, stakeholder, organizational factor, and objective for programmatic effectiveness. The operational definitions of benchmarking and indicators herein provide a basic overview of these terms regarding program evaluation; however, hiring a consulting firm specializing in creating and measuring benchmarks and indicators may be necessary and pragmatic. Remember to budget for the program evaluation activities. Since program evaluation is paramount to success and sustainability, budgeting around 1%-5% or more of the direct costs to complete program evaluation tasks each funding year may be prudent.

In summary, effective STEM program evaluations are valuable mechanisms to demonstrate the programmatic activities that are working and the methods that are not working. Incorporating formative and summative assessments will create opportunities for making changes during the program that impact success and guarantee compliance with project goals, outcomes, and impacts. Creating several rubrics to assist the evaluation process is a sound practice to enhance evaluation endeavors. Quality rubrics are helpful evaluation tools to facilitate formative and summative assessment of goal attainment, provide helpful feedback, and ensure comprehension of program expectations. Rubrics guide the nature of the evaluation process and should be constructed and disseminated to project team members and participants prior to the start of the program.

## ACKNOWLEDGMENTS

This work was supported by grants from the National Science Foundation (EES - 2205612 and EES - 2232563).

## REFERENCES

1. Borrego, M., Mastronardi, M., Choe, H., & Hartman, R. (2021). The impact of undergraduate research experiences on participants' career decisions. Journal of STEM Education: Innovations and Research, 22, 1-8.
2. Brace, J., Baiduc, R., Drane, D., Flores, L., Beitel, G., & Lo, S. (2018). Design, implementation, and evaluation of a multi-disciplinary professional development program for research mentors. Mentoring & Tutoring: Partnership in Learning, 26, 377-399.
3. Bradford, B., Beier, M., & Oswald, F. (2021). A meta-analysis of university STEM summer bridge program effectiveness. CBE - Life Sciences Education, 20, 1-14.
4. Bradley, E., & Mead, N. (2022). Underrepresented faculty mentoring at a distance: Program implementation and evaluation. Mentoring & Tutoring: Partnership in Learning, 30, 142-158.
5. Bruthers, C., & Matyas, M. (2020). Undergraduates from underrepresented groups gain research skills and career aspirations through summer research fellowship. Advances in Physiology Education, 44, 525-539.
6. Chan, Z., & Ho, S. (2019). Good and bad practices in rubrics: The perspectives of students and educators. Assessment & Evaluation in Higher Education, 44, 533-545.
7. Cooper, C., Rocha-Ruiz, M., & Herzon, C. (2020). Using integrated logic models to build equity in students' pathways and systemic change. Equity & Excellence in Education, 53, 105-120.
8. Dede, H. (2022). Evaluation of STEM SOS model: Pre-service science teachers' opinions. International Journal of Progressive Education, 18, 44-56.
9. Flowers, L. A., Flowers, L. O., & Moore, J. L., III. (2016). Advancing educational outcomes in science, technology, engineering, and mathematics at historically Black colleges and universities. University Press of America.
10. Ghebreyessus, K., Ndip, E., Waddell, M., Asojo, O., & Njoki, P. (2022). Cultivating success through undergraduate research experience in a historically black college and university. Journal of Chemical Education, 99, 307-316.
11. Greer, C., Chi, C., & Hylton-Patterson, N. (2023). An empirical evaluation of a summer bridge program on college graduation at a small liberal arts college. Journal of College Student Retention: Research, Theory & Practice, 24, 909-923.
12. Howley, C., Campbell, J., Cowley, K., & Cook, K. (2022). Pathways and structures: Evaluating systems changes in an NSF INCLUDES alliance. American Journal of Evaluation, 43, 632-646.
13. Jones, N., Azzam, T., Wanzer, D., Skousen, D., Knight, C., & Sabarre, N. (2020). Enhancing the effectiveness of logic models. American Journal of Evaluation, 41, 452-470.
14. Okulu, H., & Oguz-Unver, A. (2021). The development and evaluation of a tool to determine the characteristics of STEM activities. European Journal of STEM Education, 6, 1-14.
15. Onyura, B., Lass, E., Lazor, J., Zuccaro, L., & Hamza, D. (2022). Vitalizing the evaluation of curricular implementation: A framework for attending to the "How and Whys" of curriculum evolution. Advances in Health Sciences Education, 27, 553-572.
16. Pitre, D., Mlsna, T., & Mlsna, D. (2022). REU-INFEWS program: Results from innovations at the nexus of food, energy and water security program. Journal of STEM Education: Innovations and Research, 23, 12-21.
17. Reeves, P., Claydon, J., & Davenport, G. (2022). Program evaluation practices and

the training of PhD students in STEM studies in graduate and postdoctoral education, 13, 109-131.
18. Rickles, J., Zeiser, K., & West, B. (2018). Accounting for student attrition in power calculations: Benchmarks and guidance. Journal of Research on Educational Effectiveness, 11, 622-644.
19. Rockinson-Szapkiw, A., Sharpe, K., & Wendt, J. (2022). Promoting self-efficacy, mentoring competencies, and persistence in STEM: A case study evaluating racial and ethnic minority women's learning experiences in a virtual STEM peer mentor training. Journal of Science Education and Technology, 31, 386-402.
20. Sabtiawan, W., Yuanita, L., & Rahayu, Y. (2019). Effectiveness of authentic assessment: Performances, attitudes, and prohibitive factors. Journal of Turkish Science Education, 16, 156-175.
21. Strycker, J. (2016). Logic models as a way to support online students and their projects. Journal of Educators Online, 13, 135-150.
22. Türk, N., Kalayci, N., & Yamak, H. (2021). Evaluation of the effectiveness of science, technology, engineering and mathematics (STEM) curriculum designed and implemented for undergraduate programs of faculty of education. International Online Journal of Education and Teaching, 8, 1401-1428.
23. Windsor, A., & Ivey, S. (2018). Using mid-semester evaluations for increasing success of STEM students: A case-study. Journal of STEM Education: Innovations and Research, 19, 21-26.
24. Yang, D., Xu, D., Yeh, J., & Fan, Y. (2019). Undergraduate research experience in cybersecurity for underrepresented students and students with limited research opportunities. Journal of STEM Education: Innovations and Research, 19, 14-25.
25. Zhao, M. (2022). Summer science academy in chemistry as a gateway to STEM for matriculating first-generation and other underrepresented students. Journal of Chemical Education, 99, 759-767.